METHOD FOR CONTROLLING EXPLOSIONS IN OPEN MINES

Field of the Invention

The present invention relates to the field of mining and excavations, and more specifically to a blasting method that allows obtaining improved blasting results in open mines and excavations, and by using less explosive materials and fewer drill holes, comparing to conventional blasting techniques that are utilized for blasting a site having essentially the same surface area.

Background of the Invention

There are several blasting methods that are utilized in the field of open mines and excavations, most of which involve the use of conventional drill holes that are vertically drilled and arranged according to a preferred array. The term "conventional drill hole" refers to a drill hole that is essentially cylindrical, with an essentially constant diameter along its longitudinal axis. Different geometrical arrangements, or arrays, of conventional drill holes are commonly used, which arrangements depend on the geological and topographical characteristics of the site that is to be blasted and on the desired blasting results.

Currently, different types of conventional drill holes are used. For example, conventional drill holes are filled, according to some conventional methods, with alternating layers of explosives and non-explosive buffer material, such as soil, rocks and rubble, and the number, relative location and ratio of these layers are determined, in general, in accordance with the nature of the site that is to be blasted.

No matter what the arrangement of the various explosives and buffer layers is in a conventional drill hole, the use of conventional drill holes has a major drawback due to its cylindrical shape; i.e., the major blasting impact, that is generated by detonating an explosive material placed in the drill hole, propagates in circles on planes that are essentially parallel with respect to one another and perpendicular to the longitudinal axis of the drill hole, and, therefore, the blasting results are not optimal with respect to the pulverized rock mass surrounding the source of the explosion; i.e., the explosion impact attenuates rather fast with respect to the distance from the drill hole, resulting in narrow fracture does. In addition, some portion of the blasting impact propagates also towards and through the opening of the drill hole, resulting in wasted blast impact. In order to compensate for the relatively poor blasting effect of an individual conventional drill hole, a large number of deep drill holes (i.e., usually between 14 and 15 meters deep) are used per given area of the site that is to be blasted, for obtaining the desired blasting effect. Consequently, relatively large amounts of explosive charges must be poured or put into such drill holes. The large number of deep drill holes causes extensive costs in drilling time, machinery wear and human labor.

WO 02/42711 discloses a drill hole blasting arrangement, which includes drill holes 30. Each of the drill holes 30 contains an explosive layer 50 and a buffer material 44, tamped with layer 60. However, the method disclosed in WO 02/42711 suffers from the drawback described above in connection with the cylindrical shape of the drill holes.

It is therefore an object of the present invention to provide a blasting arrangement which will allow reducing the number of blast drill holes per given area of a site that is to be blasted, compared to the number of drill holes required in conventional blasting techniques.

It is another object of the present invention to allow blasting a site of relatively large area with a reduced amount of explosives, compared to conventional blasting techniques.

It is a further object of the present invention to reduce the costs of drilling holes for a given site that is to be blasted.

It is still further object of the present invention to reduce the costs of evacuation of blasted rocks/soil from the blasted area.

It is a still further object of the present invention to pulverize rock mass to a greater degree than is possible with conventional blasting techniques.

Other objects and advantages of the invention will become apparent as the description proceeds.

Summary of the Invention

The present invention relates to the field of mining and excavations, and more specifically to a blasting method that allows obtaining improved blasting results in

open mines and excavations, and by using less explosive materials and fewer drill holes, in comparison to conventional blasting techniques employed on a blasted site having essentially the same area.

The blasting method disclosed in the present invention is characterized by the use of a blasting arrangement, which comprises an array of drill holes that have a unique shape. According to the present invention, the upper portion or top of each of the uniquely shaped drill holes is cylindrical, and the lowermost portion or bottom thereof has a shape close to spherical, which may be defined as being "onion-like". The term "onion-like" shape, with respect to the bottom of the drill hole, refers to a hollow, or cavity, that preferably meets the condition $0.5 < \eta < 0.9$, where $\eta = \frac{D}{H}$ ($D -$ the diameter at the widest horizontal plane of the hollow, H – the height of the hollow).

The diameter of the onion-like shaped bottom is much larger than that of the cylindrical portion. The blasting method that utilizes drill holes with onion-like bottoms is hereinafter referred to as the "onion blasting method", and the onion-shaped drill hole bottom is hereinafter simply referred to as the "onion". Likewise, a drill hole that has an onion-like bottom is hereinafter referred to as an "onion drill hole".

According to the present invention, the new blasting method comprises:

a) Drilling as many as required conventional, viz. cylindrical, drill holes in a site that is to be blasted. The drill holes are drilled according to a preferred array, for allowing obtaining an optimum blasting result;

b) For each of the cylindrical drill holes, performing the following steps:

b.1) Imparting an onion shape to the bottom portion of the drill hole. The maximum diameter of the onion is larger than the diameter of the cylindrical drill hole, so that when an explosive charge placed therein (i.e., in the onion) is detonated, the resulting blasting impact propagates essentially evenly to all spatial directions, viz. radiates from the center of the onion;

b.2) Filling the onion with a primary explosive charge;

b.3) Filling a first portion of the drill hole, above said primary explosive charge, with buffer material, such as soil and/or rubble;

b.4) Filling a second portion of the drill hole, above said buffer material, with a secondary explosive charge;

b.5) Filling a third portion of the drill hole with additional buffer material, for stemming the opening of the drill hole; and

c) Detonating the primary and secondary explosive charges. The detonation of the primary charge contributes the main blasting effect, and the detonation of the secondary charge adds an additional blasting impact to the surface area of the blasted site, for ensuring that rocks at the surface area essentially above the onions are disintegrated into small pieces.

By using the onion blasting method, essentially all of the explosion impact that is generated by the primary explosive charge remains "locked" underneath the surface of

the blasted site, and is utilized for disintegrating, or pulverizing, the rock/soil mass surrounding the onion.

Preferably, the onion-like shape is imparted to the bottom portion of the drill hole by:

a) Filling the bottom of the conventional cylindrical drill hole with initial explosive charge, such as ANFO (Ammonium Nitrate-Fuel Oil), which initial charge is relatively small (e.g., 12 to 15 Kg.), with respect to the primary explosive charge (e.g., 1,000 to 1,250 Kg), but large enough to impart to the bottom of the drill hole the onion-like shape; and

b) Detonating the initial explosive charge.

According to an aspect of the present invention, the bottom portion of the conventional cylindrical drill hole that is filled with the initial explosive charge (herein after "initial depth"), is preferably between 3% to 5% of the total depth of the drill hole.

According to another aspect of the present invention, imparting the onion-like shape to the bottom portion of the drill hole further includes filling some portion of the cylindrical portion of the drill hole with buffer material for stemming the opening of the drill hole before detonating the initial explosive charge. The latter stemming is herein after referred to as the "initial stemming".

According to still another aspect of the present invention, the initial stemming characteristics and/or the amount of initial explosive charge in the bottom portion of the cylindrical drill hole are utilized for obtaining wanted general shape and

dimensions of the onion, according to known geological and topographical characteristics of the site to be blasted. By "initial stemming characteristics" it refers to the length of the initial stemming, the relative location of the initial stemming within the cylindrical portion of the drill hole, and the type of the buffer material (e.g., deposit of gravel or sand, etc.) utilized for the initial stemming.

According to an aspect of the present invention, all of the drill holes are drilled to the same depth, which is between 80% to 90% of the "Bench Height", which Bench Height is known in the art as the depth of the layer of a rock/soil mass that is to be blasted (e.g., 15 meters). Optionally, however, different drill holes may be drilled to different depths.

Preferably, the relative depth, or lengths, of the first, second and third portions are approximately 60%, 15% and 15%, respectively, of the overall depth, or length, of the drill holes.

Preferably, the depth of the drill holes is approximately 13 meters, the diameter of the cylindrical portions of the drill hole is approximately 8 inches, and the lengths of the first, second and third portions of the drill hole, which are filled with buffer material, secondary explosive charge and additional buffer material, respectively, are approximately 7.8, 1.95 and 1.95 meters, respectively.

Preferably, the length of the onion is between 8% to 11% of the total depth of the drill hole, and its maximum diameter is 1.00 meter, and the onion is filled with a primary

explosive charge, (e.g., ANFO), the weight of which ranges between 800 and 1,250 kilograms.

Preferably, the array of drill holes comprises essentially parallel rows of drill holes; the spacing between each two adjacent drill holes in the same row is 18 meters; and the spacing between each two adjacent rows (generally known in the art as the "Burden") is 16 meters. However, different arrangements and different spacing of drill holes may be utilized, depending on the geological and topographical characteristics of the site that is to be blasted.

Brief Description of the Drawings

The above and other characteristics and advantages of the invention will be better understood through the following illustrative and non-limitative detailed description of preferred embodiments thereof, with reference to the appended drawings, wherein:

- Fig. 1 (prior art) schematically illustrates an exemplary conventional drill hole;
- Fig. 2 schematically illustrates a typical ("onion") arrangement of a drill hole, according to a preferred embodiment of the present invention;
- Figs. 3a and 3b show field test of detonation of initial, secondary and primary explosive charges, respectively, in accordance with the present invention; and
- Fig. 4 schematically illustrates a conventional blasting arrangement versus a blasting arrangement in accordance with the present invention.

Detailed Description of Preferred Embodiments

Fig. 1 (prior art) schematically illustrates an example of a conventional drill hole. Conventional drill hole 10 has the shape of a cylinder, the diameter of which, 10/1, is essentially constant along its longitudinal axis 11. Drill hole 10 includes a first portion 12 that contains the explosive charge 12/1, and a second portion 13 that contains a stemming material 13/1. When explosive charge 12/1 is detonated, the main explosion impact propagates in horizontal circles, or waves, the axis of which coincides with axis 11. In addition, due to the fact that the diameter 12/1 along axis 11 of drill hole 10 is essentially constant, a portion of the explosion impact bursts towards and through opening 14 of drill hole 10, clearing the stemming material 13/1 and, thus, contributing essentially nothing to the breakage, or pulverizing, of the rock mass surrounding drill hole 10.

Fig. 2 schematically illustrates a typical ("onion") arrangement of a drill hole, according to a preferred embodiment of the present invention. Drill hole 20 includes first, second and third portions 21, 22 and 23, respectively, which have relative lengths, or depths, equal to approximately 60%, 15% and 15%, respectively, of the overall length, or depth, of the drill hole, which overall length could be, e.g., 13 meters, and which contain buffer material 21/1, secondary explosive charge 22/1 and stemming material 23/1, respectively. Accordingly, the lengths of portions 21, 22 and 23, are approximately 7.8m, 1.95m and 1.95m, respectively.

The onion-shaped bottom 24 allows the blasting impact, which results from the detonation of primary explosive charge 24/1, to be directed, essentially evenly, to all spatial directions, from the center of the onion outwards, as schematically illustrated

by arrows 26/1, 26/2, 26/3 (i.e., downwards components), 26/4, 26/5, 26/6, 26/7 (i.e., upwards components), 26/8, 26/9 (i.e., leftwards components), and 26/10, 26/11 (i.e., rightwards components). Of course, some of the blasting impact, which is caused by the detonation of primary explosive charge 24/1, is directed straight upwards, to and through opening 28 of drill hole 20. Because diameter 27 of the onion is chosen to be very large compared to diameter 25 of drill hole 20, a "locking" effect is obtained, according to which the major portion of the blasting impact remains locked underground, and is utilized for disintegrating the corresponding rock/soil mass.

Due to the distribution of the blasting energy as described above, the blasting energy causes rock mass to be pulverized to a greater degree than is possible with conventional blasting arrangement.

Preferably, the diameter 25 of drill hole 20 is approximately 8 inches, the overall depth of drill hole 20 is approximately 13 meters, the diameter 27 of the onion is approximately 1 meter and the height of the onion is approximately 1.30 meters. However, other dimensions may be utilized, which relate to the geological and/or typographical characteristics of the rocks/soil in the site that is to be blasted.

A typical onion (i.e., an onion having a diameter of 100 centimeters and height of 1.3 meters) could contain approximately 1,200 kilograms of primary explosive charge. Preferably, the secondary and primary explosive charges are ANFO.

Fig. 3 depicts field tests of detonations of secondary and primary explosives, according to a preferred embodiment of the present invention. As explained before, a plurality of conventional drill holes are drilled, after which a relatively small initial explosive charge is placed in the bottom of each (not shown) drill hole. Section (a) of Fig. 3 shows simultaneous detonation of these initial explosive charges, the purpose of which is to impart the onion shape to the corresponding drill hole bottom, in the way described hereinabove. After the creation of the onions, a primary explosive charge is placed in each of the onions (not shown), after which the first, second and third portions of every drill hole are filled with buffer material and secondary explosive charge, as described in connection with Fig. 2. Section (b) of Fig. 3 shows simultaneous detonation of the primary and secondary explosive charges. As shown in section (b) in Fig. 3, only a relatively small portion of each blast is visible, the result being indicative of the "locking" effect that is described above in connection with the blasting impact.

Obtaining an explosion as described above and shown in Fig. 3(b) has several advantages beside those described in connection with drilling time and costs; i.e., such explosions are far less dangerous to spectators than explosions resulting from conventional blasting arrangements, because, as seen in Fig. 3(b), the risk of airborne rock fragments is significantly reduced, due to the blasting impact being "locked" underground, as explained hereinabove.

Fig. 4 schematically illustrates an exemplary conventional blasting array and an exemplary blasting array in accordance with the present invention, for comparison

purposes. Fig. 4(a) shows the exemplary conventional blasting array, which consists of 28 conventional drill holes, each of which has a depth of 15 meters, which includes an "under drilling" depth, which is an extra drilling that goes beyond the depth of the Bench Height, for compensating for the fact that the maximum blasting impact is generated not at the immediate vicinity of the explosion point, but, rather, at some distance away from the explosion point. The drill holes are arranged in an 8m x 8m "drilling network"; i.e., the spacing between two adjacent drill holes in each line is 8 meters, and the spacing between each two adjacent lines is also 8 meters. Accordingly, the array of drill holes is intended for blasting a site having an area of approximately 1,728 square meters.

Fig. 4(b) shows an exemplary blasting array comprising only 6 onion drill holes, for blasting a site that has, for comparative purposes, the same area as that to which Fig. 4(a) refers, viz. approximately 1,728 square meters. The onion drill holes are arranged in 18m x 16m drilling network; i.e., the spacing between two adjacent drill holes in each line is 18 meters, and the spacing between each two adjacent lines is 16 meters.

In contrast to Fig. 4(a), only 6 (onion) drill holes are required for blasting a site of the same area, and the blasting arrangement shown in Fig. 4(b) is superior, both in drilling costs and time, blasting results and safety to personnel involved in handling the blasting. The significant reduction in drilling costs is apparent from the data contained in Table 1 below.

Table 1 includes comparative data, indicative of the advantages of the exemplary blasting arrangement illustrated in Fig. 4(b) over the exemplary conventional blasting arrangement illustrated in Fig. 4(a).

TABLE 1

Technical parameter	Data/Results for blasting array of Fig. 4(a)	Data/Results for blasting array of Fig. 4(b)
Quantity of rock/soil to be blasted (A)	A=1,500,000 m^3	A=1,500,000 m^3
Distance between adjacent drill holes in a same row	8 meters	16 meters
Distance between adjacent rows	8 meters	18 meters
Depth of each drill hole (B)	B=14 meters	B=13 meters
Diameter of each drill hole	8 inches	8 inches
Drilling network (C)	C= 8x8=64 m^2	C= 16x18=288 m^2
Surface to be drilled (D) D= A/B	D=107,143 m^2	D=107,143 m^2
Number of required drill holes (E) E= D/C	E= 1,674	E= 372
Required drilling length (F) F= E x B	F= 25,112 meters	F= 4,650 meters
Drilling rate G (in m/hour), for standard DML drilling machine	G=50 m/HR	G=50 m/HR
Required total drilling hours (H) H= F/G	H= 502 Hours	H= 93 Hours
Cost for one drilling hour (I), in $/HR	I= 246 $	I= 246 $
Total drilling cost (J) J= H x I	J= 123,549 $	J= 22,879 $
Drilling costs per 1 m^3 (K) of blasted rock/soil K= J/A	**K= 0.082 $**	**K= 0.015 $**

Referring to Table 1, the drilling costs per cubic rock/soil to be blasted are much higher (i.e., 5.47:1) when using conventional drill holes than when using the onion blasting method, as is shown in Table 1; i.e., K=0.082 $ in the first case, versus K=0.015 $ in the second case. Likewise, because only (E=) 372 drill holes are required in the onion blasting arrangement, compared to (E=) 1,674 drill holes required in the conventional blasting arrangement, it is clear that a considerably decreased amount of explosive charges and explosive accessories (e.g., fuses, detonating cords, booster explosive materials, etc.) is required in the onion blasting arrangement.

As described hereinabove, the blasting impact, or the energy generated after detonating each primary explosive charge, is utilized to its full extent for pulverizing rocks/soil surrounding the primary explosive charges (i.e., *onions*), and, therefore, the costs of the evacuation of the disintegrated rocks/soil, by, e.g., loading the pulverized rocks/soil onto truck, are also reduced.

Fig. 5 schematically illustrates utilization of initial stemming prior to the detonation of the initial explosive charge, according to the present invention. Length "L" and height "H" of initial stemming 52, as well as the buffer material (e.g., deposit of gravel or sand, etc.), from which initial stemming 52 consists, may be determined so as to obtain an onion with wanted shape and dimensions according to known geological and/typographical characteristics of the blasted area surrounding drill hole 50. However, as described above, initial stemming 52 is an option.

The above embodiments have been described by way of illustration only and it will be understood that the invention may be carried out with many variations, modifications and adaptations, without departing from its spirit or exceeding the scope of the claims.